Case Study

"The Nordex N60/1300 kW Wind Turbine and the 'Gearless' Enercon E-58"

Suggested Activities

Unit 3

- Describe the fundamental differences between the two turbines.
- Which components are not needed for the Enercon E-58?
- Summarise why direct drive machines may offer a route to higher output turbines?

Unit 5

- Examine the power curve for the Nordex machine and describe which power control strategy the turbine utilises.

The 'Gearless' Wind Turbine
ENERCON E-58/850kW

HIGH TORQUE/LOW SPEED (DIRECT DRIVE) GENERATORS

There is currently a great deal of interest in direct-drive generators (i.e. generators couple to the drive shaft of the wind turbine without a speed increasing gearbox). As turbine size increases, the relative cost of the gearbox becomes more important. For a doubling of wind turbine diameter, rated power will quadruple, and rotor torque, which is closely related to gearbox cost, will increase by a factor of eight.

E58 TURBINE DATA	
Manufacturer:	ENERCON GmbH
Model:	E-58
Rated capacity:	850 kW
Rotor Diameter:	58 m
Hub height:	from 70 m (variety of towers and bases)
Rotor with pitch control	
Type:	upwind rotor with active pitch control
Direction of rotation:	clockwise
Number of blades:	3
Swept area:	2,642 m²
Blade material:	fiberglass (reinforced epoxy) with integral lightning protection
Rotor speed:	variable, 10-23 rpm
Pitch control:	Three synchronised blade pitch systems with emergency supply
Generator with drive train	
Hub:	rigid
Bearings:	double-row tapered roller bearings
Generator:	direct-driven ENERCON ring generator
Breaking system:	• 3 independent pitch-control systems with emergency supply • rotor brake • rotor lock for service and maintenance
Yaw control:	Active through adjustment gears friction damping
Cut-in wind speed:	2.5 m/s
Rated wind speed:	11.5 m/s

The Nordex N60/1300 kW Wind Turbine

THE DESIGN

The Nordex N60/1300 kW wind turbine has been developed on the basis of the Nordex N54/1000 kW. The goal during the development of the N60/1300 kW wind turbine has been to develop a "megawatt-class" turbine that is capable of producing electricity at a low price , and at the same time to maintain the excellent reliability experienced from the N54/1000 kW turbine i.e. incremental change rather than a totally new design.

The N60/1300 kW wind turbine is designed as a 3-bladed, horizontal-axis, stall-regulated wind turbine, with a relatively large rotor diameter in relation to the nominal generator rating.

The wind turbine is designed for a survival wind speed of 70 m/s according to IEC (65 m/s according to GL1). All components are therefore dimensioned with a high safety factor, which secures a long lifetime of the entire turbine. Each component is designed for much higher loads than it will normally be exposed to.

THE ROTOR

The Nordex N60/1300 kW wind turbine has a rotor diameter of 60m and a swept area of 2828 m^2.

The hub is made of cast iron, which gives a strong and robust construction. Furthermore this material reduces transferred noise from the rotor to the turbine structure.

The Nordex N60/1300 kW turbine is stall-regulated, which means that the blades are fixed to the hub in a predetermined tip-angle. The rotor is therefore generally maintenance free, and contains a minimum of moving mechanical parts which could become worn during operation.

THE BLADES

The blades profile as well as the material has been optimised in order to exploit the wind energy to a maximum, and in order to reduce the blade surface and weight as much as possible, thereby reducing loads and stress in the entire wind turbine.

The blades are manufactured primarily of fibreglass reinforced polyester and carbon fibres. The surface is coated in a light grey colour in order to prevent light reflections.

The blade tips are pivotable, and can be turned 85 ° in relation to the rest of the blade, and thereby act as an aerodynamic brake, and the primary braking system of the turbine. During normal operation of the turbine, the blade tips are maintained in operational position by pressurised hydraulic cylinders, which are located in each blade-root. If unintentionally the rotor should exceed the nominal rotational speed, or if hydraulic pressure is lost, the centrifugal force will cause the blade tips to deploy, thereby slowing down the rotor and acting as a truly fail-safe system.

MAIN SHAFT

The main shaft is manufactured in alloy steel. It has a state of the art, 3-point support, with a solid plummer block spherical roller bearing supporting the shaft at the rotor in order to absorb the rotor thrust. In the gearbox the shaft is supported by two cylindrical roller bearings and the gearbox unit again rests on two supports. The shaft is connected to the gearbox by a shrink-fit coupling.

GEARBOX

The gearbox is a custom designed 3-stage gearbox with the first stage as high torque planetary gear and the second and third stages as helical stages. The planetary stage is ideal for obtaining and transferring the rotor torques of the shaft, and is at the same time a compact and robust design. The gearbox is fitted in two strong rubber bushings in order to dampen the noise and load peaks, so that when extreme loads occur, the gearbox and bearings are protected against damage.

The gear oil is cooled by a heat exchanger, connected to the cooling system of the generator. Monitoring of the oil temperature ensure that the oil reaches its optimum temperature as fast as possible, and at the same time is kept constantly at the optimum temperature. The gears and bearings therefore obtain a constant and optimal lubrication.

GENERATOR

The generator is a double-wound 4/6-pole asynchronous machine with two separate windings, and a nominal effect of 250 kW and 1300 kW respectively. The generator is optimised for the highest efficiency at ¾ load, which under most wind conditions gives the optimum kWh production.

The generator is designed for insulation class F but is only operated to class B. This together with the efficient liquid cooling of the generator, ensures an optimum operating temperature, which again prolongs the lifetime of the generator considerably. The flexible rubber coupling to the gearbox provides a robust and maintenance-free solution.

YAW SYSTEM

The active yaw system which enables the wind turbine to be positioned correctly in the wind, is based on a 4-point-ball-bearing slewing ring.

The yawing of the turbine is done by 3 planetary gears, which are each driven by a thyristor controlled electric driven motor, resulting in the loading of the yaw gears being equally distributed.

The yaw brake consists of a large disk brake activated by 6 hydraulic brake calibers. Furthermore, each yaw gear has a separate brake built into the fast stage. The complete system ensures a smooth yawing procedure, and that the nacelle is fixed when the yawing is inactive. In this way we ensure that there is no load on the yaw gears and drives, when the turbine is not yawing.

Two mutually independent wind vanes give signals to the master computer, which controls the yawing procedure of the turbine.

The system ensures that the turbine is positioned correctly in the wind at all times, thereby resulting in the optimal power production and minimum stress on the turbine drive train.

BRAKE SYSTEM

The Nordex N60/1300 kW turbine has two independent braking systems.

The primary system is the aerodynamic tip-brakes.
The secondary system is the mechanical disk brake system which is located on the high speed shaft of the gearbox.

Both systems function in a fail-safe mode.

During normal operation of the turbine each blade tip is maintained in operational position by a pressurised hydraulic cylinder located in the blade root. The release of the hydraulic pressure on the cylinders, intentionally or by a failure in the system, will cause the tips to deploy and the rotor to decrease the rotational speed. When the rotor is slowed down to a certain speed, the mechanical disk brake system is activated and the turbine is smoothly brought to a standstill.

The Nordex wind turbines utilise a soft braking system on the mechanical brake. This means that the braking torque is controlled according to a rampload-function, which reduces the strain on the drive train. In this way the risk of pitting of the gearbox is minimised, and at the same time the torque in blades and drive train is reduced.

During emergency braking both the aerodynamic and mechanical braking systems are activated simultaneously.

TOWER

The Nordex N60/1300 kW wind turbine can be delivered with a conic-shaped steel tower with various hub heights.

The tower is equipped with internal ladder, safety wire, working platforms and light fixtures. The climbing to the nacelle is from the inside of the tower. The painting and corrosion protection is in accordance with ISO 12944 Class 5.

LIGHTNING PROTECTION

With the gradual increase in wind turbine tower height, the risk that the turbine could be hit by a lightning also increases.

This fact has lead Nordex to take the utmost precautions in order to minimise the risk that a lightning strike will cause damage to parts of the turbine. The lightning protection system of the Nordex N60/1300 kW wind turbine is therefore designed according to the IEC-1024-1 standard.

If a lightning strikes the turbine blade or the nacelle, the advanced protection system will safely lead the lightning current to the wind turbine earthing system, with minimum risk of damage to any part in the turbine.

The electrical and electronic components in the turbine are protected by means of varistors, and the turbine internal communication is performed via optical fibre technique, which is immune to voltage peaks.

CONTROLLER

The wind turbine controller has two independent computers. The master computer is located in the switchboard in the bottom of the tower, and a slave is located in the nacelle. All inputs from sensors and transducers are collected and assessed by the slave-computer and transmitted to the master computer which supervises the overall operation of the turbine.

The communication between the master and the slave computer is via optic fibre technology, which enables a reliable and fast exchange of signals. A large amount of data can be read from the display-board connected to the master computer. A keyboard in the front of the switchboard is utilised for changing between different read-outs and at the same time can be utilised to change parameter settings for the turbine if required.

REMOTE MONITORING

The Nordex N60/1300 kW wind turbine is fully prepared for remote monitoring and control. A telephone-connection is all that is needed for this system to be functional. From a Personnel Computer a full range of data can be read from the turbine.

In case of an error, the turbine controller automatically reports the event, and the data in the controller is stored so that it is possible to see what happened just before, and when the error occurred.

WIND TURBINE OPERATION

The Nordex N60/1300 kW wind turbine operates fully automatically. This means that the turbine automatically starts (wind-start) when the wind speed reaches 3-4 m/s. When the rotor/generator reaches synchronising speed, the generator is connected to the grid by a thyristor soft-connection. The turbine produces electricity for supply to the grid, as long as the wind speed is between 3-25 m/s. At wind speeds between approx. 3 and 7 m/s the 250 kW generator is connected to the grid, and at wind speeds between approx. 7 and 25 m/s, the 1300 kW generator is connected to the grid. At wind speeds higher than 25 m/s, the turbine will be shut down for safety reasons.

The turbine will automatically re-start after any shut down if no error is present. If the turbine has an error, this has to be analysed and reset before the turbine starts up again.

Summary of Technical Specifications

Rotor Type 3-bladed, horizontal axis, upwind Rotor diameter 60 m. Swept area 2.828 m2 Power regulation Stall RPM 19 / 12,7 RPM Cut-in / cut-out wind 3,5 / 25 m/s. Nominal output at 15 m/s. Survival windspeed 70 m/s (IEC) Calculated lifetime of turbine 20 years

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Gear Type Combined, 3-stage gearbox, 1-stage planetary, 2-stage helical Manufacturer Flender, or similar Nominal load 1335 kW Ratio 1:79,7 Oil-quantity 230 l.

Blades Manufacturer LM, Aerpac or similar. Blade length 29 m. Material Carbon and glass fibre reinforced polyester, or glass fibre reinforced epoxid-resin Length of blade tip 3,8 m. Lightning protection Included

Generator Nominal power 1300/250 kW Type Asynchronous, water-cooled Synchronous speed 1515 / 1010 rpm Protection classification IP54 Efficiency at 75 % load 96,50%

Yaw system Type Active yawing, electrically Yaw control By windvane Yaw rate $0,6^o$ per second

Controller Type Microprocessor Grid connection Via soft-power controller Remote communication Included UPS Included

Braking system Aerodynamic, type Pivotable blade tips Areodynamic, activation By controller or hydraulic. Passive activation by centrifugal force at overspeed Mechanical, type Fail safe, hydraulical Mechanical, location On high speed shaft Number of brake calibers 2 Time to bring rotor to rest from max. rpm App. 6 sec.

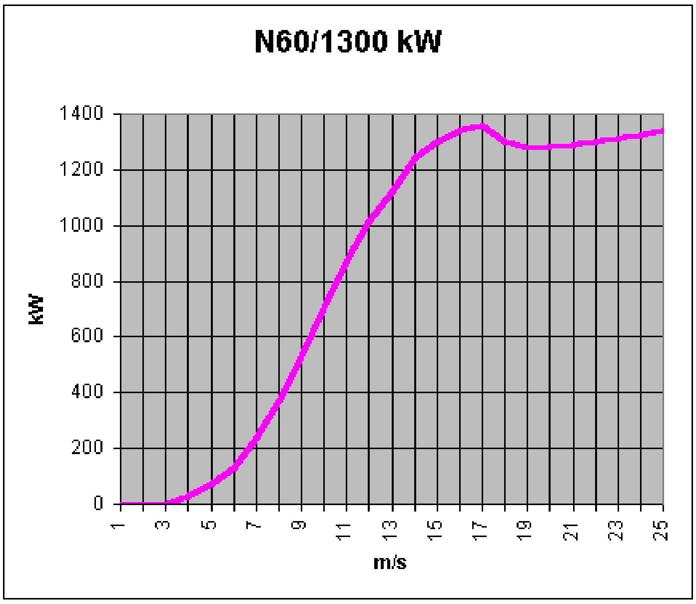
Towers Type Tubular (cone-shaped) Hub heights 46, 60, 65 or 69 m. Corrosion protection Sandblasted and painted with 250 my epoxy-paint

Weights Nacelle, excl. rotor and hub 49,2 t. Rotor, incl. hub 18,2 / 18,9 t. Gearbox 12,2 t. Generator 6,8 t. Tower, 46 / 60 / 65 / 69 m. 66 t. / 85 t. / 91 t. / 104 t.

The Power Curve

(Air density: 1.225 kg/m^3, Air temperature: 15 ºCelcius).

m/s	kW
3	0
4	28
5	73
6	131
7	240
8	375
9	535
10	704
11	871
12	1016
13	1125
14	1246
15	1301
16	1344
17	1360
18	1300
19	1282
20	1288
21	1292
22	1300
23	1313
24	1328
25	1344



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Calculated Annual Production in kWh for the NORDEX N60/1300 kW Wind Turbine from Wind Data Measured in 40 m. Height

N60/1300

Average annual wind speed at 40 m, height	46m, hub height	50m, hub height	60m, hub height	69m, hub height
4.0 m/s	705,000	723,000	761,000	790,000
4.5 m/s	1,043,000	1,068,000	1,125,000	1,169,000
5.0 m/s	1,439,000	1,474,000	1,552,000	1,614,000
5.5 m/s	1,880,000	1,926,000	2,028,000	2,110,000
6.0 m/s	2,352,000	2,408,000	2,535,000	2,637,000
6.5 m/s	2,838,000	2,905,000	3,056,000	3,178,000
7.0 m/s	3,327,000	3,403,000	3,577,000	3,717,000
7.5 m/s	3,807,000	3,892,000	4,086,000	4,243,000
8.0 m/s	4,271,000	4,363,000	4,573,000	4,745,000
8.5 m/s	4,710,000	4,808,000	5,033,000	5,217,000
9.0 m/s	5,120,000	5,223,000	5,460,000	5,653,000
9.5 m/s	5,497,000	5,604,000	5,849,000	6,049,000
10.0 m/s	5,838,000	5,947,000	6,197,000	6,402,000

The calculated annual productions are based on: Air-density: 1.225 kg/m^3, Air-temperature: 15^{o}C, k-parameter: 2.00

Please note that the average wind speed is measured in 40 m, height,